the refractive layer is formed by deposition in a self aligned manner within the trench.

12. (Original) A waveguide as defined in claim 1 wherein:

the refractive layer completely encircles the core.

27. (Added) A waveguide as defined in claim 11 wherein:

the core is formed by deposition in a self aligned manner within an opening of the refractive layer extending along the trench.

28. (Added) A waveguide as defined in claim 1 wherein:

the refractive layer and the core are located within the trench.

29. (Added) A waveguide as defined in claim 4 wherein:

the refractive layer and the core are located within the trench.

Remarks

Reconsideration is respectfully requested of the objection and rejection set forth in the office action mailed March 30, 2001. In that office action, claims 13-26 were withdrawn from consideration in view of a response to a telephone restriction requirement, confirmation of the election was requested, claims 3 and 7 were objected to as indefinite, and claims 1-4, 11 and 12 were rejected under 35 USC 103(a) as obvious from Lee (5,281,305). In addition, claims 5-10 were noted as containing allowable subject matter and as being allowable if amended. This Amendment and Response is intended to respond to these rejections and objections, and to place the application in form for allowance.

A petition for two months extension of time and the fee therefor accompanies this Amendment and Response. The time for response to the March 30 office action is thereby extended to August 30, 2001.

Claims 1-12 are now pending.

The election made without traverse on March 19, 2001 is hereby confirmed. Claims 13-26 have been canceled and are intended to be presented in a divisional application.

The informalities of claims 3 and 7 have been corrected as suggested.

Original claim 5 has been rewritten into independent form by incorporating the subject matter of original claim 1. In accordance with the Examiner's notation of allowable subject matter, claims 5-10 should now be allowable.

It is respectfully requested that U.S. patent 5,281,305 to Lee be cited on PTO Form 892. The Form 892 attached to the March 30 Office Action does not mention this patent, even though the Lee patent is the basis for the obviousness rejection. Moreover, U.S. patent 5,387,269 has been incorrectly cited on Form 892 as identifying Lee as the inventor. The correct inventor of U.S. patent 5,387,269 is Nijander. Correction is respectfully requested.

Reconsideration of the obviousness rejection of claims 1-4, 11 and 12 is also respectfully requested.

Claim 1 is for a graded index of refraction waveguide. In the manner set forth more specifically in claim 1, the graded index of refraction characteristics are achieved from a layer of dielectric material defining a trench, a refraction layer conforming to the side walls of the trench and a core of optically transmissive material conforming to the refractive layer. The graded index of refraction characteristics of the waveguide result because the index of refraction of the core is greater than the index of refraction of the refractive layer, and the index of refraction of the refraction layer is greater than the index of refraction of the dielectric material. Because of this three layer differentiation in the indices of refraction, the light energy is better confined to the waveguide, losses are minimized, and the quality of the optical signal is enhanced, as described in the application:

> Because of the "graded" indices of refraction obtained by the relatively higher index of refraction of core material 32, the relatively intermediate index of refraction of the refractive material 30 and the relatively lower index of refraction of the dielectric material 26, only a small portion of the light energy enters the dielectric material 26 and is lost. The graded index of refraction characteristics of the waveguide 22 confines the majority of the optical energy in the waveguide 22, which reduces losses in optical signal energy, and enhances the quality of the optical signal. The optical losses can be

reduced to almost zero by the time any portion of the optical signal reaches the dielectric material 26. (Application, page 15, lines 4-16)

These improvements are also described throughout the application at page 7, lines 18-22; page 9, lines 16-23; and page 26 lines 12-23, among other locations.

Lee (5,281,305) does not describe or suggest a graded index of refraction waveguide. Instead, Lee describes a simple waveguide with no graded index of refraction.

Lee describes the placement of a borosilicate glass (BSG) layer 18 within a trench of a silicon dioxide layer 10, and and optically transmissive Phosphosilicate glass (PSG) layer 20 placed within the BSG layer, as shown in Fig. 6. Lee also describes additional BSG layers 28 and 34 surrounding another vertically spaced optically transmissive element 30, as shown in Fig. 12. However, Lee does not disclose or suggest that the surrounding BSG layers 18, 28 and 34 have an index of refraction which is greater than the index of diffraction of the silicon dioxide 10. Instead, Lee teaches that the BSG layers 18, 28 and 34 have an index of refraction which is equal to the index of refraction of the silicon dioxide layer 10:

> Since the refractive index of the borosilicate glass and the silicon dioxide are nearly equal, the structure can be represented (optically) as shown in Fig. 13. Waveguides 20 and 30, therefore, essentially reside in a single index medium with the medium acting as a cladding thereabout. (Lee, column 3, lines 66 to column 4, line 3.)

Indeed, the single index structure described in Lee appears to be the acknowledged prior art structure, over which the invention described in claim 1 is a significant improvement:

> Typical waveguides used as optical interconnects in IC-like structures comprise a singular channel material having a predetermined index of refraction which is greater than the index of refraction of the cladding material surrounding the channel. Consequently, losses in signal intensity are minimized because the refraction of light energy into the cladding material is minimized due to the lower index of refraction of the cladding material compared to the index of refraction of the channel material. However, the single index of refraction of the channel material eliminates the ability to

tailor the waveguide to a lossless or near-lossless condition. (Application, page 5, lines 4-15)

There is simply no basis in Lee for the obviousness rejection of claim 1. Lee is acknowledged prior art over which the present invention is a significant improvement. Nothing in Lee teaches or suggest a graded index of refraction waveguide. Of course, the disclosure of the present invention cannot be properly used as a hindsight basis for rejecting claim 1. Therefore, the obviousness rejection based on Lee is believed to be inappropriate and should be withdrawn.

Original claims 2-4, 11 and 12, and added claims 27-29, depend on claim 1 and should be allowable in conjunction with claim 1. In addition however, these dependent claims present features which are not disclosed or suggested by Lee.

Claim 4 has been amended to incorporate subject matter from claim 3 as an antecedent basis so that claim 4 can depend on claim 1. Claim 4 has been amended in this manner to avoid potential questions of inconsistency with respect to the dielectric layer contacting the core as stated in claim 2. Claim 2 was originally present in the dependency chain of claim 4.

It is believed that the application is now in condition for allowance, and such action is respectfully requested.

The Examiner is encouraged to telephone the undersigned for the purpose of resolving any additional issues that would inhibit the immediate allowance of this application.

Respectfully submitted,

Date: 8/27/01

By: _____

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Verne C. Hornbeck and Derryl D.J. Allman	)	
Serial No. 09/217,183	)	Group Art Unit: 2877
Filed: December 21, 1998	)	
	)	Examiner: L. G. Lauchman
For: ON-CHIP GRADED INDEX OF REFRACTION OPTICAL WAVEGUIDE AND DAMASCENE METHOD OF FABRICATING THE SAME	)	

Amended Claims Compared to Previous Claims
Upon Entry of Amendment and Response to First Office Action

Deletions are shown by strikeout and insertions by double underlining:

In the Claims:

1. **(Original)** A graded index of refraction waveguide formed in an integrated circuit-like structure having a substrate, comprising:

at least one layer of dielectric material positioned above the substrate and defining a trench having side walls, the dielectric material having an index of refraction;

a refractive layer of optically transmissive material adjoining the side walls within the trench and conforming to the side walls, the refractive layer having an index of refraction; and

a core of optically transmissive material adjoining the refractive layer within the trench and conforming to the refractive layer, the core having an index of refraction; and wherein:

the index of refraction of the core is greater than the index of refraction of the refractive layer, and the index of refraction of the refractive layer is greater than the index of refraction of the dielectric material.

2. **(Original)** A waveguide as defined in claim 1 wherein:

the refractive layer surrounds the core except on one side; and

the dielectric material contacts the core on the one side where the refractive layer does not surround the core.

3. **(Amended Once)** A ~~method~~**waveguide** as defined in claim 2 wherein:

the refractive layer is U-shaped and surrounds the core except on the one side.

4. **(Amended Once)** A waveguide as defined in claim ~~3~~**1 wherein:**

the refractive layer is U-shaped and surrounds the core except on the one side; and further comprising:

a cap of the refractive material extending across the one side of the core between ends of the U-shaped refractive layer, the cap adjoining and conforming to the core and the refractive layer, the cap having essentially the same index of refraction as the U-shaped refractive layer; and **wherein:**

the cap and the U-shaped refractive layer ~~encircling~~**encircle** the core.

5. **(Amended Once)** ~~A waveguide as defined in claim 1 further comprising:~~ **A graded index of refraction waveguide formed in an integrated circuit-like structure having a substrate, comprising:**

at least one layer of dielectric material positioned above the substrate and defining a trench having side walls, the dielectric material having an index of refraction;

a first refractive layer of optically transmissive material adjoining the side walls within the trench and conforming to the side walls, the first refractive layer having an index of refraction;

a second refractive layer of optically transmissive material ~~in addition to the refractive layer first aforesaid, the second refractive layer located between the first refractive layer and the core, the second refractive layer~~ adjoining and conforming to the first refractive layer ~~and~~**within** the ~~core~~**trench**, the second refractive layer having an index of refraction; ~~and wherein:~~

a core of optically transmissive material adjoining and conforming to the second refractive layer within the trench, the core having an index of refraction; and wherein:

the index of refraction of the first refractive layer is greater than the index of refraction of the dielectric material, the index of refraction of the second refractive layer is ~~less than the index of refraction of the core and~~ greater than the index of refraction of the first refractive layer~~.~~**, and the index of refraction of the core is greater than the index of refraction of the second refractive layer.**

6. **(Original)** A waveguide as defined in claim 5 wherein:

the first and second refractive layers surround the core except on one side; and

the dielectric material contacts the core on the one side of the core where the first and second refractive layers do not surround the core.

7. **(Amended Once)** A ~~method~~**waveguide** as defined in claim 6 wherein:

the first and second refractive layers are each U-shaped;

the second U-shaped refractive layer surrounds the core except on the one side of the core; and

the first U-shaped refractive layer surrounds the second U-shaped refractive layer except on the one side of the core.

8. **(Original)** A waveguide as defined in claim 7 further comprising:

a cap of the refractive material extending across the one side of the core between ends of one of the first or second U-shaped refractive layers, the cap extending between the core and the dielectric material, the cap having essentially the same index of refraction as the U-shaped refractive layer to which the cap is connected; and wherein:

the cap and the one of the U-shaped refractive layers to which the cap is connected encircle the core.

9. **(Original)** A waveguide as defined in claim 7 further comprising:

a first cap of refractive material extending across the one side of the core between ends of the first U-shaped refractive layer, the cap adjoining and conforming to the core and the refractive layer, the cap having essentially the same index of refraction as the first U-shaped refractive layer;

and

a second cap of refractive material extending across the one side of the core between ends of the second U-shaped refractive layer, the second cap having essentially the same index of refraction as the second U-shaped refractive layer;

the first cap adjoins and conforms to the dielectric material and the second cap;

the second cap adjoins and conforms to the core and the first cap;

the first cap and the first U-shaped refractive layer encircles the second cap and the second U-shaped refractive layer; and

the second cap and the second U-shaped refractive layer encircles the core.

10. **(Original)** A waveguide as defined in claim 5 wherein:

the first refractive layer is formed by deposition in a self-aligned manner with the trench;

the second refractive layer is formed by deposition in a self-aligned manner with the first refractive layer; and

the core material is formed by deposition in a self aligned manner with the second refractive layer.

11. **(Original)** A waveguide as defined in claim 1 wherein:

the refractive layer is formed by deposition in a self aligned manner within the trench.

12. **(Original)** A waveguide as defined in claim 1 wherein:

the refractive layer completely encircles the core.

27. (Added) A waveguide as defined in claim 11 wherein:

the core is formed by deposition in a self aligned manner within an opening of the refractive layer extending along the trench.

28. (Added) A waveguide as defined in claim 1 wherein:
the refractive layer and the core are located within the trench.

29. (Added) A waveguide as defined in claim 4 wherein:
the refractive layer and the core are located within the trench.